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INHERITANCE OF KERNEL ARRANGEMENT IN SWEET CORN

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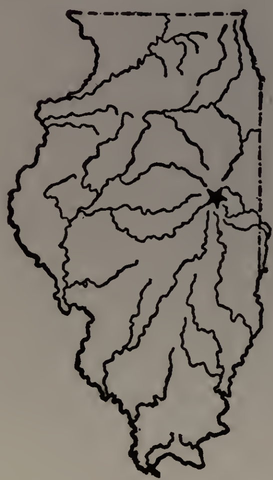

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INHERITANCE OF KERNEL ARRANGEMENT IN SWEET CORN

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Ears of the Country Gentleman variety of sweet corn differ in appearance from those of other varieties by having an irregular or "zigzag" arrangement of kernels. This condition becomes fixed to a considerable degree under careful and long-continued selection. However, there is a constant recurrence of individuals which are more or less rowed. The lack of uniformity among the segregating ears, as well as the variability in the percentage of segregates, indicated at first that this might be a form of polymorphism, and suggested a careful study of the character.

MORPHOLOGY OF KERNEL ARRANGEMENT

Stewart[6] and Weatherwax[8] explain the peculiar arrangement in Country Gentleman Sweet Corn as being due to the crowded condition of the kernels, which in turn is the result of the development of both the upper and lower flowers of the pistillate spikelet. In rowed varieties the lower flower remains primordial and only the upper flower functions, and the familiar rowed appearance results. The phylogenetic significance of the functioning of the lower flower is still somewhat in doubt, according to Stratton[7] and others. It is probable that reduction in the number of pistillate flowers is the more highly specialized form. It appears, therefore, that the distinguishing difference between Country Gentleman and rowed varieties is in the functioning of the lower flower.

Kempton[4] mentions a sweet corn in which the irregular kernels are due to the indiscriminate arrangement of spikelets. Weatherwax,[8] however, claims that he has found no variety of corn in which the spikelets are not arranged in rows on the cob, irrespective of whether one flower functions, or both.

In working with Country Gentleman sweet corn, the authors have frequently noted the occurrence of rowed individuals in open-pollinated strains selected by the ear-row method. Occasionally such ears were distinctly rowed like other varieties of sweet corn, but more often the rowed condition was confined either to the butt or to the tip, as mentioned by Stratton.[7] Specimens in which the rowing was intermediate, or indistinct, were of frequent occurrence. Further investigation proved that rowing occurred in strains of Country Gentleman obtained from a number of widely different sources. The theory of Weatherwax[9] would seem to account for this phenomenon. He

states, "At times, however, a set of conditions, presumably environmental, may limit the size of the grain or increase the length of the cob sufficiently that the rows are almost straight, altho each spikelet is still producing two grains." On this basis one would expect that most of the large-sized Country Gentleman ears should have the kernels in rows over all or part of the ear and, at the same time, contain two kernels in each spikelet. The authors have observed that all the distinctly rowed ears or parts of ears in Country Gentleman cultures have spikelets with only a single functional flower, which accounts for the regularity in the arrangement of the kernels. In the intermediate type, where the rowing is present but more or less indistinct, paired kernels borne on a single pedicel are interspersed with single kernels in which the lower flower has remained primordial. This intermediate type of rowing differs, however, from another type which appears the same but is merely due to incomplete pollination in an otherwise distinctly rowed ear.

MATERIALS AND METHODS

Narrow Grain Evergreen is a 16- to 20-rowed sweet corn having an obscure origin. Certain commercial strains of this variety were selected from crosses between Country Gentleman and Stowell's Evergreen. The strains used by the authors, however, were the result of long-continued selection from Stowell's Evergreen. This may account for the fact that all but one of the rowed parents proved to be homozygous for kernel arrangement.

Country Gentleman, when true to type, is characterized by "shoepeg" kernels and by an irregular or zigzag kernel arrangement extending over the entire ear.

Crosses were made in 1924 between parents which had been previously inbred for two generations. The F_2 and F_3 generations were grown from ears obtained by selfing F_1 and F_2 plants in 1925 and 1926 respectively. Back crosses between the F_1 progenies and the parental strains were made in all cases, but many of them failed to fertilize owing to differences in time of maturity and a poor growing season.

The ears in each generation were harvested as mature corn and later classified for kernel arrangement. Such classification included all the ears that were filled well enough so that the type of kernel arrangement could be determined with reasonable accuracy.

Wherever the segregating progenies were separated into three or more phenotypic classes, the χ^2 method was used for calculating the closeness of fit between the observed and expected frequencies. The probability values were taken from Elderton's tables as given by Pearson.[5]

In the case of 3:1 segregations the probable errors were calculated by the formula P.E. $= \pm 0.6745 \sqrt{pqn}$, in which n is the total number of individuals, and p and q are the percentages, .75 and .25, corresponding to the ratios concerned.

Review of Previous Work

Halsted and Owen,[3] in crosses between Country Gentleman and several rowed types of sweet corn, observed "a strong preponderance of straight rows" in the progenies. In some progenies they found only an occasional ear which was entirely zigzag, but many ears occurred in which the upper third was irregularly disposed while the remainder of the ear was rowed.

East and Hayes[1] stated that the zigzag, or irregular, arrangement of kernels on the ears of Country Gentleman sweet corn is a dominant character due to a single genetic factor. They drew their conclusions from the behavior of the F_1 and F_2 progenies of a single irregular ear which had been selfed. This selfed ear produced a progeny having approximately 3 normal to 1 irregular. This departure from the usual behavior of a heterozygous monohybrid, when selfed, was explained as being due to "reversed" or "fluctuating dominance." A single progeny obtained by selfing a plant producing a normal ear gave all normal ears, which further led to the conclusion that the normal class was a homozygous recessive. In addition to the above type of irregularity there is also mentioned by East and Hayes[1] another kind of irregular kernel arrangement which they called "physiological fluctuations" which were found to be non-heritable. A confusion of these two types made it difficult to classify the segregates. The authors experienced the same difficulty in classifying their material.

Emerson,[2] in reporting the results of a cross between dent corn (rowed) and pop corn (irregular), states that the arrangement of grains in regular rows is perhaps the dominant character. The segregation in the F_2 generation seemed to indicate that there is a single factor concerned. However, extreme fluctuations in the F_1 progeny, reaching as far as the irregular (zigzag) type, threw doubt upon the single factor hypothesis unless such fluctuations are regarded as the "physiological fluctuations" of East and Hayes.[1]

EXPERIMENTAL RESULTS

Progeny Segregations and Their Classification

Crosses between Country Gentleman and Narrow Grain Evergreen produced F_1 progenies which approached the Narrow Grain Evergreen parent in type of rowing (Fig. 1). The rowed kernel arrangement must, therefore, be incompletely dominant over the irregular type.

TABLE 1.—CLASSIFICATION OF THE PHENOTYPES IN THE INHERITANCE OF ROWING IN SWEET CORN

Description of phenotypic classes	Genotypic classes	Ratio			Ratio for Groups I, II, III, IV		
		Observed	Expected	Deviation	Observed	Expected	Deviation
I—Distinctly rowed	$Pi_1Pi_1Pi_2Pi_2$ $Pi_1Pi_1Pi_2pi_2$	2.7	3	−.3	2.7	3	−.3
II—Less distinctly rowed							
Rows continuous	$Pi_1pi_1Pi_2Pi_2$	1.9	2	−.1	5.8	6	−.2
Rows not continuous	$Pi_1pi_1Pi_2pi_2$	3.9	4	−.1	...	..	....
III—Intermediate							
A. More nearly rowed than zigzag							
1. Rows continuous	$Pi_1Pi_1pi_2pi_2$	1.1	1	.1	...	..	....
2. Rows not continuous	$Pi_1pi_1pi_2pi_2$	2.1	2	.1	6.4	6	.4
B. More nearly zigzag than rowed							
1. Slightly rowed at butt or tip	$pi_1pi_1Pi_2Pi_2$	1.1	1	.1	...	..	....
2. Slight trace of rowing	$pi_1pi_1Pi_2pi_2$	2.1	2	.1	...	..	....
IV—Rowing completely absent, true zigzag (Country Gentleman) type	$pi_1pi_1pi_2pi_2$	.9	1	−.1	.9	1	−.1
		...	16	....	...	16	....

TABLE 2.—GENETIC COMPOSITION OF PARENTS AND F_1 PROGENY

Cross No.	F_1 genotypes	Pedigree No. of parents ♀ X ♂	Probable genetic composition of parents	Description F_1 ears (open pollinated)
1002	$Pi_1pi_1pi_2pi_2$	207–1 X 306–1 (Narrow Grain Evergreen X Country Gentleman)	$Pi_1Pi_1pi_2pi_2$ X $pi_1pi_1pi_2pi_2$	Intermediate
1003	$Pi_1pi_1Pi_2pi_2$ $Pi_1Pi_1Pi_2pi_2$	207–2 X 390–1 (Narrow Grain Evergreen X Country Gentleman)	$Pi_1pi_1Pi_2Pi_2$ X $Pi_1Pi_1pi_2pi_2$	Rowed
1004	$Pi_1pi_1Pi_2pi_2$ $Pi_1Pi_1Pi_2pi_2$ $Pi_1pi_1Pi_2Pi_2$	306–2 X 207–3 (Country Gentleman X Narrow Grain Evergreen)	$Pi_1pi_1Pi_2pi_2$ X $Pi_1Pi_1Pi_2Pi_2$	Rowed
1005	$Pi_1pi_1Pi_2pi_2$ $Pi_1pi_1Pi_2Pi_2$	208–1 X 383–1 (Narrow Grain Evergreen X Country Gentleman)	$Pi_1Pi_1Pi_2Pi_2$ X $pi_1pi_1Pi_2pi_2$	Rowed
1006	$Pi_1pi_1Pi_2pi_2$	209–1 X 449–1 (Narrow Grain Evergreen X Country Gentleman)	$Pi_1Pi_1Pi_2Pi_2$ X $pi_1pi_1pi_2pi_2$	Rowed
1008	$pi_1pi_1Pi_2pi_2$	449–2 X 207–4 (Country Gentleman X Narrow Grain Evergreen)	$pi_1pi_1pi_2pi_2$ X $Pi_1pi_1Pi_2pi_2$	Segregated[1]
1010	$Pi_1pi_1Pi_2pi_2$	306–3 X 228–1 (Country Gentleman X Narrow Grain Evergreen)	$pi_1pi_1pi_2pi_2$ X $Pi_1Pi_1Pi_2Pi_2$	Rowed
1015	$Pi_1Pi_1Pi_2pi_2$ $Pi_1pi_1Pi_2Pi_2$	449–3 X 209–2 (Country Gentleman X Narrow Grain Evergreen)	$Pi_1pi_1Pi_2pi_2$ X $Pi_1Pi_1Pi_2Pi_2$	Rowed
1018	$Pi_1pi_1Pi_2pi_2$	216–1 X 390–2 (Narrow Grain Evergreen X Country Gentleman)	$Pi_1Pi_1Pi_2Pi_2$ X $pi_1pi_1pi_2pi_2$	Rowed
1022	$Pi_1pi_1Pi_2pi_2$ $Pi_1pi_1Pi_2Pi_2$	437–1 X 140–1 (Narrow Grain Evergreen X Country Gentleman)	$Pi_1Pi_1Pi_2Pi_2$ X $pi_1pi_1Pi_2pi_2$	Rowed

[1]Segregated as follows: 19 rowed, 42 intermediate, 19 zigzag.

There was some variation, however, in the degree of rowing among the F_1 progenies from the different crosses. The dominance of the rowed kernel arrangement, as indicated by the authors' experiments, is in accordance with the observations of Halsted[3] and Emerson.[2]

F Progenies. Much of the parental material was found to be heterozygous. It may be noted that two or more types of F_2 segregation occurred in each cross. Crosses 1003, 1004, 1005, and 1022 (Tables 16, 17, 18, and 22) gave rise to both dihybrid and monohybrid ratios, while Cross 1015 (Table 23) produced two types of monohybrid segregations. Obviously in each of these crosses the F_1 plants which were selfed were not all of the same genetic composition. In Table 2 are listed the crosses and the F_1 factorial formulae necessary to account for the various F_2 segregations obtained. (Where there was only one type of segregation, it may be assumed that the F_1 plants were alike genetically).

Since only 1♀ and 1♂ plant were used in making each cross, at least one of the parental plants must have been heterozygous. Altho all the strains used as parents had been previously inbred for two generations, many of these by subsequent inbreeding proved to be heterozygous. In columns 3 and 4 of Table 2 are given the pedigree numbers of the parental plants used in each cross and their probable genetic composition. Where the same parental strain was used in two or more crosses, individual plants were used in each cross, as shown by the last figure of the pedigree number.

The F_1 open-pollinated progenies from the crosses mentioned above, with two exceptions as shown in column 5 of Table 2, were rowed and fairly uniform. Each of the F_1 plants from these crosses must have contained both the Pi_1 and Pi_2 factors, for the "rowed" kernel arrangement, either one or both being heterozygous, as shown in column 2. In Cross 1002, where the F_1 generation contained only the Pi_1 factor, the open-pollinated progeny was intermediate. Cross 1008 produced an F_1 progeny which was much more variable than the rest and seemed to give a segregation of 1 rowed: 2 intermediate: 1 zigzag. An F_1 segregation of this type might be obtained if the Narrow Grain Evergreen parent contained the factors Pi_1 pi_1 Pi_2 pi_2 and the Country Gentleman parent was homozygous for pi_1 and pi_2. The F_1 progeny would be expected to contain the following four types in approximately equal numbers: Pi_1 pi_1 Pi_2 pi_2, Pi_1 pi_1 pi_2 pi_2, pi_1 pi_1 Pi_2 pi_2, and pi_1 pi_1 pi_2 pi_2. Since the F_1 classification was made before the various types of rowing were well understood, it is probable that the Pi_1 pi_1 Pi_2 pi_2 type was classed as "rowed" while the Pi_1 pi_1 pi_2 pi_2 and pi_1 pi_1 Pi_2 pi_2 types, combined, made up the intermediate class. All the F_1 plants from which F_2 progenies were grown must have been of the same genetic composition since only one type of F_2 segregation was obtained (see Table

25). The remaining crosses, Nos. 1002, 1006, 1010, and 1016, were between homozygous parents.

In Table 3 are listed the numbers of the inbred strains from which the parental plants were selected, together with the necessary gametic composition of each. It will be noted that, with one exception, the Narrow Grain Evergreen strains were homozygous. Narrow Grain Evergreen strain 207, together with all the Country Gentleman strains, were heterozygous, containing one or both of the factors for rowing. In column 3 is given a very brief description of the behavior of each strain during five years of inbreeding. These descriptions are very consistent with the genetic composition of the strains as determined by the crosses reported in this paper.

TABLE 3.—GAMETIC COMPOSITION OF PARENTAL STRAINS AND THEIR BEHAVIOR DURING FIVE YEARS OF INBREEDING

	Gametes produced by parental strain	Behavior of parental strain
Narrow Grain Evergreen		
207	Pi_1Pi_2 — Pi_1pi_2 — pi_1Pi_2	Segregated for kernel arrangement
208	Pi_1Pi_2	No segregation, all rowed
209	Pi_1Pi_2	No segregation, intermediate type
216	Pi_1Pi_2	No segregation, all rowed
228	Pi_1Pi_2	No segregation, all rowed
437	Pi_1Pi_2	No segregation, all rowed
Country Gentleman		
140	pi_1pi_2 — pi_1Pi_2	All Country Gentleman type (possibly $pi_1pi_1Pi_2Pi_2$ included)
366	pi_1pi_2 — pi_1Pi_2 — Pi_1pi_2	Tends to row
383	pi_1pi_2 — pi_1Pi_2	All Country Gentleman type (possibly $pi_1pi_1Pi_2Pi_2$ included)
390	pi_1pi_2 — Pi_1pi_2	Poorly filled. No observations on kernel arrangement
449	pi_1pi_2 — pi_1Pi_2 — Pi_1pi_2	Segregated for rowing

F_2 Progenies. Twenty-two F_2 progenies from seven different crosses segregated naturally into four distinct groups: Group I, in which the kernels were distinctly rowed; Group II, in which the kernels were less distinctly rowed than in Group I; Group III, an intermediate group which was neither rowed nor zigzag; and Group IV, a zigzag group. The F_2 progenies were first classified under the above groups, which gave a ratio of 2.7:5.8:6.4:0.9 (Tables 1 and 4), or approximately a 3:6:6:1 ratio. This typically dihybrid ratio led to the assumption that kernel arrangement is due to the interaction of at least two genetic factors, which were arbitrarily designated Pi_1 and Pi_2, being derived from the word "pistillate."

This method of separating the F_2 progenies into four phenotypic classes did not prove satisfactory, owing to the lack of uniformity in the individuals under Groups II and III. It was found that Group II could be further subdivided into two classes based on the continuity of the rows. Group III was also divided into two subgroups, one approaching the rowed type and the other resembling the zigzag type. Each subgroup was further separated into two classes. The F_2 material was therefore classified into eight phenotypic classes as shown in Table 1 and Figs. 2 to 9.

Groups I and IV may be readily distinguished. In Group I the rows are clearly defined and continuous from butt to tip. All the embryos face the tip of the ear. In Group IV the rows appear to be entirely absent due to the zigzag arrangement of the kernels, which have a typical "shoepeg" form in contrast with the flattened kernels in Group I.

The chief difference between Groups I and II is that the rows are less regular in Group II (see Figs. 2, 3, and 4). Subgroup III-A (Figs. 5 and 6) resembles Group II, while Subgroup III-B (Figs. 7 and 8) tends more toward the zigzag type (Fig. 9) in Group IV. When Figs. 3 and 4 are compared, however, with Figs. 5 and 6 it will be noted that the chief difference is in the slight offsetting of the kernels. Altho Subgroup III-B resembles Group IV, it cannot be included with the latter owing to the traces of rowing.

Modifications in the Genetic Expression of Rowing

East and Hayes[1] mention two kinds of irregular (zigzag) kernel arrangements in sweet corn. The first is a "physiological fluctuation" which is not inherited, while the second is "a definitely inherited character, or possibly a set of characters." The first type of irregular kernel arrangement will always be encountered in sweet corn cultures. The cause lies in the development of less than the normal number of kernels. Frequently only the butts and tips of the ears are affected in this way often to the extent of being entirely bare. Less frequently the spikelets which fail to develop kernels are scattered over the entire ear. It is obvious that any condition which prevents the development of the entire complement of kernels on the ear will impair the genetic expression of kernel arrangement. In the case of a genetically rowed type, the spaces left vacant by undeveloped kernels will tend to be filled by those remaining. This probably gives rise to the physiologically irregular type of East and Hayes.[1] The genetically pure zigzag type of kernel arrangement is modified in a similar manner. The kernels likewise spread into the vacant spaces and thus lose their "shoepeg" form, but more serious still the lower flower of the spikelet often fails to develop in scattered areas, thus giving the ear a partially rowed appearance. These and other modifications which obscure the genetic expression of rowing lead to errors

in classifying the individuals in a given progeny. Such errors become cumulative within a large population of numerous progenies and are confined mainly to the rowed classes as will be shown later.

It is often impossible to properly classify inbred strains of sweet corn because their weakness leads to the indeterminate or anomalous genetic expression of rowing. Abnormalities in cob growth, such as fasciations, have a similar effect.

ANALYSIS OF THE INHERITANCE OF KERNEL ARRANGEMENT

Segregations in the F Progenies

The genotypes expected in the F_2 generation on the basis of the two-factor hypothesis and the proportionate number in each are shown in Table 1. Pi_1 Pi_1 Pi_2 Pi_2 and Pi_1 Pi_1 Pi_2 pi_2 could not be classified separately and are assumed to be phenotypically the same.

The twenty-two F_2 progenies mentioned above were separated into the eight classes shown and are summarized in Table 4. The agreement between the observed and expected numbers in Table 4 is not close. It will be noted that the observed frequencies in the three-rowed classes are less than the expected. On the other hand, in the four intermediate classes (Table 4) the observed number exceeds the expected. Reference to the individual F_2 progenies (Tables 16 to 22 inclusive) indicates that the observed frequencies in the classes mentioned vary nearly always in the same direction. Thus the deviations in Table 4 are really due to a series of cumulative errors which are without doubt due to the obscuring effects of non-heritable modifying factors.

The segregations in Table 4, in view of the large deviations, do not by themselves substantiate the two-factor hypothesis for the arrangement of kernels on the ear, but when taken in conjunction with Tables 16 to 22 inclusive it is evident that such an interpretation is the one most closely in accord with the facts.

In addition to the twenty-two families referred to above, sixteen F_2 progenies gave monohybrid ratios in the F_2 generation. These are summarized in Tables 5, 6, 7, and 8.

The progenies in Table 5 give a 3:1 ratio. The dominant phenotype is distinctly rowed, whereas the recessive is intermediate and more nearly rowed than zigzag. The recessive class in no way resembles the true Country Gentleman type. F_2 segregations of this type were secured by selfing individuals having a Pi_1 Pi_1 Pi_2 pi_2 genetic composition. Three selfs segregated in this way, are shown in Tables 16, 17, and 23. In the four above-mentioned tables, the data clearly fit a 3:1 expectancy.

TABLE 4.—SUMMARY OF F_2 SEGREGATIONS FOR ROWING FROM CROSSES BETWEEN NARROW GRAIN EVERGREEN AND COUNTRY GENTLEMAN SWEET CORN

Cross No.	Number of families	Totals	Group I		Group II		Group III				Group IV
			Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1003	7	838	124		92	209	65	117	61	116	54
1004	1	203	32		22	45	13	27	17	33	14
1005	3	807	151		103	205	50	102	52	104	40
1006	2	287	48		39	81	22	39	19	35	4
1010	2	295	50		41	63	20	36	21	39	25
1018	3	516	89		62	122	38	74	34	69	28
1022	4	249	46		30	53	19	34	18	33	16
Total	22	3 195	540		389	778	227	429	222	429	181
Expected	..	3 195	599.1		399.4	798.8	199.7	399.4	199.7	399.4	199.7
Deviation	..	.....	−59.1		−10.4	−20.8	27.3	29.6	22.3	29.6	−18.7

$\chi^2 = 19.0032$ P = .0082

Segregations by groups:

		Group I	Group II	Group III	Group IV
Total	3 195	540	1167	1307	181
Expected	3 195	599.1	1198.1	1198.1	199.7
Deviation	.....	−59.1	−31.1	108.9	−18.7

$\chi^2 = 18.2868$ P = .0004

TABLE 5.—SUMMARY OF THE F_2 PROGENIES FROM SELF-POLLINATED $Pi_1Pi_1Pi_2pi_2$ F_1 PLANTS

Cross No.	Number of progenies	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1003	1	243	179		....	....	64	....	....	....	....
1004	1	201	151		....	....	50	....	....	....	....
1015	1	191	143		....	....	48	....	....	....	....
Total	3	635	473		....	....	162	....	....	....	....
Expected	..	635	476.2		....	....	158.8	....	....	....	....

Deviation = 3.2 ± 7.36 $\qquad \frac{\text{Dev.}}{\text{P.E.}} = .43$

TABLE 6.—SUMMARY OF THE F_2 PROGENIES FROM SELF-POLLINATED $Pi_1pi_1Pi_2Pi_2$ F_1 PLANTS

Cross No.	Number of progenies	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2Pi_2
1004.......	1	128	34	60	34
1005.......	1	369	93	185	91
1015.......	3	567	138	283	146
1022.......	1	54	13	26	15
Total.......	6	1118	278	554	286
Expected...	..	1118	279.5	559.0	279.5
Deviation...	..	....	−1.5	−5.0	6.5

$\chi^2 = .2039$ $P > .6065$[1]

[1]Values of P are not given in Elderton's tables when χ^2 is less than 1. The value of P is .6065 when $\chi^2 = 1.0000$.

TABLE 7.—SUMMARY OF THE F_2 PROGENIES FROM SELF-POLLINATED $Pi_1pi_1pi_2pi_2$ F_1 PLANTS

Cross No.	Number of progenies	Total	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 pi_2pi_2
1002.......	2	299	64	154	81
Expected...	..	299	74.8	149.5	74.8
Deviation...	..	...	−10.8	4.5	6.2

$\chi^2 = 2.2087$ $P = .3377$

TABLE 8.—SUMMARY OF THE F_2 PROGENIES FROM SELF-POLLINATED $pi_1pi_1Pi_2pi_2$ F_1 PLANTS

Cross No.	Number of progenies	Total	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1008.......	5	684	173	349	162
Expected...	..	684	171.0	342.0	171.0
Deviation...	..	...	2.0	7.0	−9.0

$\chi^2 = .6404$ $P > .6065$

The F_2 progenies shown in Table 6 segregate in a 1:2:1 ratio, only 25 percent being distinctly rowed. The recessives are intermediate but differ from those in Table 5, inasmuch as they are more nearly zigzag than rowed. They do not have the true zigzag arrangement, however. The data in Table 6 are the total of six selfs on plants having a genetic composition of Pi_1 pi_1 Pi_2 Pi_2. The data of individual F_2 progenies are shown in Tables 17, 18, 22, and 23.

The data in the five tables mentioned above agree fairly well with the expectancy based on a 1:2:1 ratio.

In Tables 7 and 8 the F_2 recessive classes were identical, each being true zigzag. The dominant classes, however, bore no resemblance to each other, indicating that they were segregating for different factors. F_2 segregations of the type shown in Table 7 could have arisen only by selfing plants with a genetic composition of Pi_1 pi_1 pi_2 pi_2. Likewise, the F_2 segregations in Table 8 were the result of selfing plants with a pi_1 pi_1 Pi_2 pi_2 factorial composition. In both Tables 7 and 8 the fit is fairly close to expectancy for 1:2:1 ratios. The data of the individual progenies are given in Table 24 (Cross 1002) and in Table 25 (Cross 1008).

The F_2 segregations in Tables 5, 6, 7, and 8 can be best explained by assuming that kernel arrangement is due to two factors. That these are by no means equal is shown by comparing the progenies in Tables 5 and 8, both of which segregate for the factor Pi_2 pi_2. The factors Pi_1 Pi_1 or Pi_1 pi_1 must be present in order to produce rowing.

The progenies in Tables 6 and 7 are segregating for the Pi_1 pi_1 factor. The expression of rowing in a genotype Pi_1 Pi_1 pi_2 pi_2 (Tables 5 and 7) is much stronger than in the pi_1 pi_1 Pi_2 Pi_2 genotype in Tables 6 and 8. Accordingly the factor Pi_1 is more necessary for the complete expression of rowing than the factor Pi_2.

Segregations in the Back-Cross Progenies

F_1 plants from four of the progenies were successfully back-crossed to the double recessive parent. Eleven progenies were obtained which without exception segregated into a 1:1;1:1 ratio, as shown in Table 9. The data for the individual families are given in Tables 26 to 29 inclusive. In the five above-mentioned tables the data clearly fit an expected 1:1:1:1 ratio.

Segregations in the F_3 Progenies

A large number of selfs were made on the F_2 progenies. The F_3 plants had greatly decreased vigor. This, combined with an unfavorable season in 1927, gave rise to low yields and caused the loss of many progenies. In addition, many of the ears were poorly filled, which fact made it difficult to classify them, especially in the rowed classes (Groups I and II).

Owing to such conditions the obscuring effect which has been mentioned previously came into play, causing a deficiency in the rowed classes shown in Table 10. By referring to the individual families in Tables 30 and 31, it will be found that the deficiencies are cumulative. In Table 32 one F_3 progeny shows a deficiency in the Pi_1 Pi_1 Pi_2 Pi_2 class, whereas the next two classes are slightly in excess of the expected. As these two plus deviations are small, they are of little importance.

TABLE 9.—SUMMARY OF THE BACK-CROSS PROGENIES OBTAINED BY CROSSING F_1 PLANTS WITH THE COUNTRY GENTLEMAN PARENT

Back Cross No.	Number of progenies	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1003	1	79	....		....	24	....	19	....	18	18
1004	2	175	....		....	38	....	43	....	51	43
1005	6	398	....		....	95	....	97	....	110	96
1018	2	212	....		....	51	....	49	....	55	57
Total	11	864	....		....	208	....	208	....	234	214
Expected	..	864	....		....	216	....	216	....	216	216
Deviation	..	...	....		....	−8	....	−8	....	18	−2

$\chi^2 = 2.1111$ P = .5523

TABLE 10.—SUMMARY OF THE F_3 PROGENIES FROM SELF-POLLINATED $Pi_1pi_1Pi_2pi_2$ F_2 PLANTS

Cross No.	Number of progenies	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1003	2	105	9		11	19	11	21	11	14	9
1005	1	61	5		9	17	4	9	5	10	2
1018	1	66	7		7	11	8	14	6	9	4
Total	4	232	21		27	47	23	44	22	33	15
Expected	..	232	43.5		29.0	58.0	14.5	29.0	14.5	29.0	14.5
Deviation	..	...	−22.5		−2.0	−11.0	8.5	15.0	7.5	4.0	.5

$\chi^2 = 31.0516$ P = .0001

TABLE 11.—SUMMARY OF THE F_3 PROGENIES FROM SELF-POLLINATED $Pi_1Pi_1Pi_2pi_2$ F_2 PLANTS

Cross No.	Number of progenies	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1004	1	59	44		....	....	15	....	....	....	....
1005	1	46	33		....	....	13	....	....	....	....
1010	2	103	75		....	....	28	....	....	....	....
Total	4	208	152		....	....	56	....	....	....	....
Expected	..	208	156		....	....	52	....	....	....	....
Deviation	..	...	−4		....	....	4	....	....	....	....

Deviation 4 ± 4.21 $\quad \frac{\text{Dev.}}{\text{P.E.}} = .95$

TABLE 12.—SUMMARY OF THE F_3 PROGENIES FROM SELF-POLLINATED Pi_1 pi_1 Pi_2 Pi_2 F_2 PLANTS

Cross No.	Number of progenies	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2Pi_2				pi_1pi_1 Pi_2Pi_2		
1015	3	169	41	84	....	....	....	44	....	....
Expected	..	169	42.2	84.5	....	....	....	42.2	....	....
Deviation	..	...	−1.2	−.5	....	....	....	1.8	....	....

$\chi^2 = .1139$ $\quad P > .6065$

TABLE 13.—SUMMARY OF THE F_3 PROGENIES FROM SELF-POLLINATED $Pi_1pi_1pi_2pi_2$ F_2 PLANTS

Cross No.	Number of progenies	Total	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 pi_2pi_2
1003........	2	81	19	48	14
1004........	2	81	21	41	19
1005........	2	130	33	72	25
1018........	1	60	15	36	9
Total.......	7	352	88	197	67
Expected...	..	352	88	176	88
Deviation..	..	...	0	21	−21

$\chi^2 = 7.5171$ P = .0240

TABLE 14.—SUMMARY OF THE F_3 PROGENIES FROM SELF-POLLINATED $pi_1pi_1Pi_2pi_2$ F_2 PLANTS

Cross No.	Number of progenies	Total	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1004........	3	214	60	97	57
1005........	1	57	13	31	13
1018........	3	235	60	112	63
Total.......	7	506	133	240	133
Expected...	..	506	126.5	253.0	126.5
Deviation..	..	...	6.5	−13.0	6.5

$\chi^2 = 1.3360$ P = .5263

TABLE 15.—SUMMARY OF THE F_3 PROGENIES FROM HOMOZYGOUS F_2 PLANTS

Cross No.	Number of progenies	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2
1003........	1	46	46	..	..
1004........	2	112	112	..	..
1010........	2	63	63	..	..
1003........	2	85	..	85	..
1004........	1	65	..	65	..
1005........	1	70	..	70	..
1006........	2	135	..	135	..
1018........	1	87	..	87	..
1006........	1	76	..	...	76

Monohybrid ratios such as were obtained in the F_2 also appeared in the F_3 generation. The summaries of these segregations are given in Tables 11, 12, 13, and 14. In Tables 11, 12, and 14 the fit is fairly close to expectancy but in Table 13 the deviations are somewhat

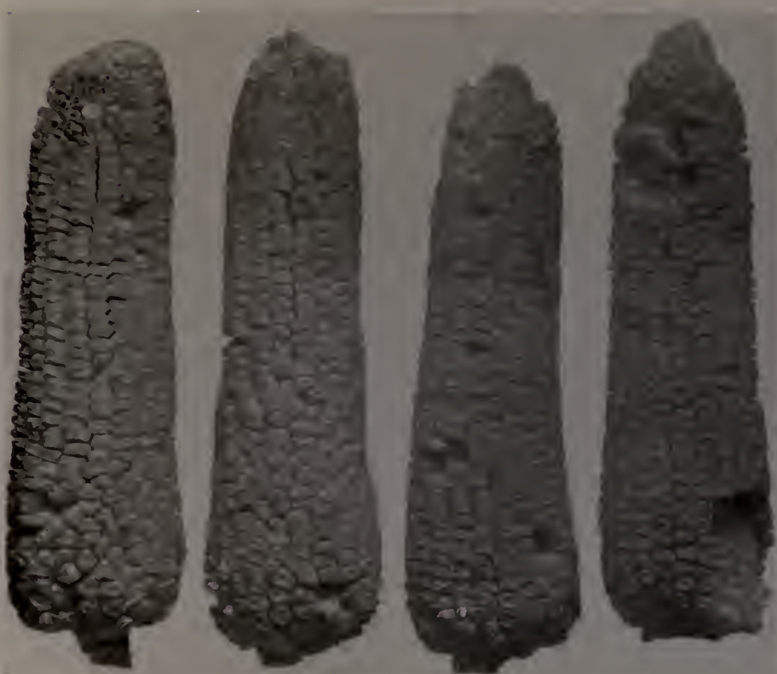

FIG. 1.—THE F_1 PROGENY FROM A CROSS BETWEEN COUNTRY GENTLEMAN AND NARROW GRAIN EVERGREEN SWEET CORN

The kernel arrangement shows that rowing is incompletely dominant.


Fig. 2
Fig 3
Fig. 4
Fig. 5

Fig. 6

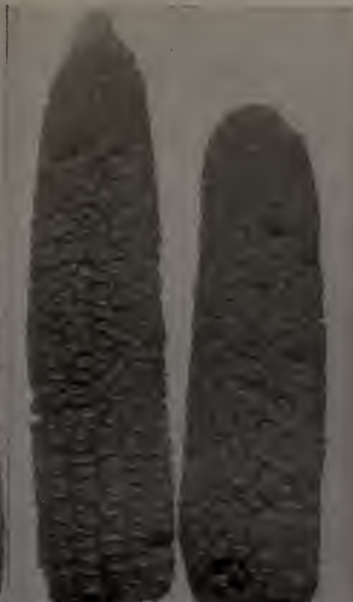

Fig. 7

Fig. 8

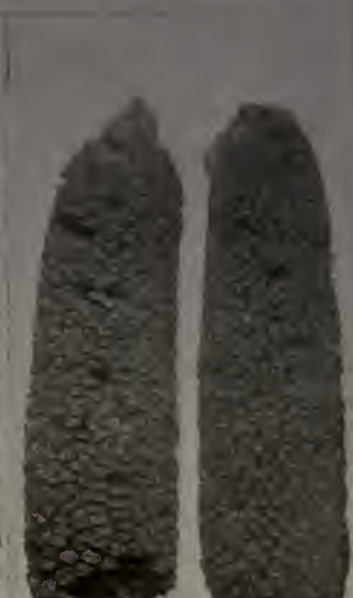

Fig. 9

RESULTS OF CROSSES BETWEEN COUNTRY GENTLEMAN AND NARROW GRAIN EVERGREEN SWEET CORN SHOWN IN FIGS. 2 TO 9

Fig. 2.—Distinctly rowed F_2 ears. The genetic composition is either Pi_1 Pi_1 Pi_2 Pi_2 or Pi_1 Pi_1 Pi_2 pi_2. This type has been designated as Group I.

Fig. 3.—Less distinctly rowed F_2 ears with rows continuous. These form part of Group II. As the rowing is continuous, the genetic composition assigned is Pi_1 pi_1 Pi_2 Pi_2.

Fig. 4.—Less distinctly rowed F_2 ears with rows not continuous. This type is less distinctly rowed than that shown in Fig. 2. It falls in Group II along with Fig. 3 but differs from Fig. 3 in that the rowing is not continuous. The assigned genetic composition is Pi_1 pi_1 Pi_2 pi_2.

Fig. 5.—Intermediate F_2 ears. This type of F_2 segregate falls into Group III-A. The kernel arrangement is intermediate but more nearly rowed than zigzag. The rowing is continuous. The assigned genetic composition is Pi_1 Pi_1 pi_2 pi_2.

Fig. 6.—Intermediate F_2 ears. This type also falls into Group III-A, but it differs from Fig. 5 in that the rowing is not continuous. The assigned genetic composition is Pi_1 pi_1 pi_2 pi_2.

Fig. 7.—Intermediate F_2 ears. This type belongs in Group III-B. The kernel arrangement differs from the types in Figs. 5 and 6 by being more nearly zigzag than rowed. The slight amount of rowing which appears is confined to butt or tip. The genetic composition is pi_1 pi_1 Pi_2 Pi_2.

Fig. 8.—Intermediate F_2 ears. This type is also classified under Group III-B. It differs from Fig. 7 in the amount of rowing, only a slight trace appearing here. The genetic composition is pi_1 pi_1 Pi_2 Pi_2.

Fig. 9.—Zigzag F_2 ears. This type has a true Country Gentleman zigzag arrangement of kernels and belongs in Group IV. The genetic composition is pi_1 pi_1 pi_2 pi_2. The ear at the right shows no trace of rowing but that at the left is somewhat doubtful.

TABLE 16.—CLASSIFICATION OF THE EARS IN EIGHT F_2 PROGENIES FROM CROSS 1003 ($Pi_1pi_1Pi_2Pi_2$ X $Pi_1Pi_1pi_2pi_2$)

F_2 Progeny No.	F_1 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1003-7	$Pi_1pi_1Pi_2pi_2$	137	22		18	38	10	17	9	19	4
1003-9	(do.)	160	28		21	43	10	19	10	20	9
1003-12	(do.)	107	12		14	23	9	22	9	14	4
1003-21	(do.)	115	24		15	30	8	13	6	12	7
1003-25	(do.)	56	8		6	12	5	9	3	8	5
1003-27	(do.)	143	4		1	32	17	26	14	30	19
1003-29	(do.)	120	26		17	31	6	11	10	13	6
Total	....	838	124		92	209	65	117	61	116	54
Expected	....	838	157.1		104.8	209.5	52.4	104.8	52.4	104.8	52.4
Deviation	....	...	−33.1		−12.8	− .5	12.6	12.2	8.6	11.2	1.6

$\chi^2 = 15.6457$ P = .0290

1003-1	$Pi_1Pi_1Pi_2pi_2$	243	179		....	....	64	....	....	....	....
Expected	....	243	182.2		....	....	60.8	....	....	....	....

Deviation = 3.2 ± 4.55 $\frac{\text{Dev.}}{\text{P.E.}} = .70$

TABLE 17.—CLASSIFICATION OF THE EARS IN THREE F_3 PROGENIES FROM CROSS 1001 ($Pl_1pl_1Pl_4pl_4 \times Pl_1Pl_1Pl_4Pl_4$)

F_3 Progeny No.	F_2 Parent genotype	Total	Pl_1Pl_1 Pl_4Pl_4	Pl_1Pl_1 Pl_4pl_4	Pl_1pl_1 Pl_4Pl_4	Pl_1pl_1 Pl_4pl_4	Pl_1Pl_1 pl_4pl_4	Pl_1pl_1 pl_4pl_4	pl_1pl_1 Pl_4Pl_4	pl_1pl_1 Pl_4pl_4	pl_1pl_1 pl_4pl_4
1001-15	$Pl_1pl_1Pl_4pl_4$	203	33		24	45	13	27	17	33	14
Expected	....	203	38.1		25.4	50.8	12.7	25.4	12.7	25.4	12.7
Deviation	....	....	−5.1		−1.4	−5.8	.3	1.6	4.3	7.6	1.3
			χ^2 = 6.1048		P = .5120						
1001-2	$Pl_1pl_1Pl_4Pl_4$	128	34	....	60	....	....	....	34	....	....
Expected	....	128	32	....	64	....	....	....	32	....	....
Deviation	....	....	2	....	−4	....	....	....	2	....	....
			χ^2 = .5000		P = .6065						
1001-10	$Pl_1Pl_1Pl_4pl_4$	201	151		....	....	50	....	....	....	....
Expected	....	201	150.8		....	....	50.2	....	....	....	....

Deviation = .2 ± 4.11 $\frac{\text{Dev}}{\text{P.E.}}$ = .05

TABLE 18.—CLASSIFICATION OF THE EARS IN FOUR F_3 PROGENIES FROM CROSS 1005 ($Pl_1Pl_1Pl_2Pl_2$ × $pl_1pl_1Pl_2pl_2$)

F_3 Progeny No.	F_2 Parent genotype	Total	Pl_1Pl_1 Pl_2Pl_2	Pl_1Pl_1 Pl_2pl_2	Pl_1pl_1 Pl_2Pl_2	Pl_1pl_1 Pl_2pl_2	Pl_1Pl_1 pl_2pl_2	Pl_1pl_1 pl_2pl_2	pl_1pl_1 Pl_2Pl_2	pl_1pl_1 Pl_2pl_2	pl_1pl_1 pl_2pl_2
1005-2	$Pl_1pl_1Pl_2pl_2$	332	65		43	88	20	38	19	41	18
1005-18	(do.)	302	53		39	76	17	38	22	39	18
1005-21	(do.)	173	33		21	41	13	26	11	24	4
Total	....	807	151		103	205	50	102	52	104	40
Expected	....	807	151.3		100.9	201.8	50.4	100.9	50.4	100.9	50.4
Deviation	....	....	−.3		2.1	3.2	−.4	1.1	1.6	3.1	−10.4

$\chi^2 = 2.4023$ $P = .9297$

F_3 Progeny No.	F_2 Parent genotype	Total	Pl_1Pl_1 Pl_2Pl_2	Pl_1Pl_1 Pl_2pl_2	Pl_1pl_1 Pl_2Pl_2	Pl_1pl_1 Pl_2pl_2	Pl_1Pl_1 pl_2pl_2	Pl_1pl_1 pl_2pl_2	pl_1pl_1 Pl_2Pl_2	pl_1pl_1 Pl_2pl_2	pl_1pl_1 pl_2pl_2
1005-11	$Pl_1pl_1Pl_2Pl_2$	369	93	....	185	....	....	....	91	....	....
Expected	....	369	92.2	....	184.5	....	....	....	92.2	....	....
Deviation	....	....	.8	....	.5	....	....	....	−1.2	....	....

$\chi^2 = .0230$ $P > .9900$

TABLE 19.—CLASSIFICATION OF THE EARS IN TWO F_3 PROGENIES FROM CROSS 1006 ($Pl_1Pl_1Pl_2Pl_2$ × $pl_1pl_1pl_2pl_2$)

F_3 Progeny No.	F_2 Parent genotype	Total	Pl_1Pl_1 Pl_2Pl_2	Pl_1Pl_1 Pl_2pl_2	Pl_1pl_1 Pl_2Pl_2	Pl_1pl_1 Pl_2pl_2	Pl_1Pl_1 pl_2pl_2	Pl_1pl_1 pl_2pl_2	pl_1pl_1 Pl_2Pl_2	pl_1pl_1 Pl_2pl_2	pl_1pl_1 pl_2pl_2
1006-1	$Pl_1pl_1Pl_2pl_2$	146	27		18	44	10	18	8	20	4
1006-5	(do.)	141	21		21	40	12	21	11	15	0
Total	....	287	48		39	84	22	39	19	35	4
Expected	....	287	53.8		35.9	71.8	17.9	35.9	17.9	35.9	17.9
Deviation	....	....	−5.8		3.1	12.2	4.1	3.1	1.1	−.9	−13.9

$\chi^2 = 14.1020$ $P = .0487$

TABLE 20.—CLASSIFICATION OF THE EARS IN TWO F_2 PROGENIES FROM CROSS 1010 ($pi_1pi_1pi_2pi_2$ X $Pi_1Pi_1Pi_2Pi_2$)

F_2 Progeny No.	F_1 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1010-2	$Pi_1pi_1Pi_2pi_2$	139	25		16	33	8	15	10	18	14
1010-3	(do.)	156	25		25	30	12	21	11	21	11
Total	....	295	50		41	63	20	36	21	39	25
Expected	....	295	55.3		36.9	73.8	18.4	36.9	18.4	36.9	18.4
Deviation	....	...	−5.3		4.1	−10.8	1.6	−.9	2.6	2.1	6.6

$\chi^2 = 5.5595$ P = .5927

TABLE 21.—CLASSIFICATION OF THE EARS IN THREE F_2 PROGENIES FROM CROSS 1018 ($Pi_1Pi_1Pi_2Pi_2$ X $pi_1pi_1pi_2pi_2$)

F_2 Progeny No.	F_1 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1018-2	$Pi_1pi_1Pi_2pi_2$	232	41		28	56	16	31	15	31	14
1018-9	(do.)	178	28		20	38	15	29	10	26	12
1018-18	(do.)	106	20		14	28	7	14	9	12	2
Total	....	516	89		62	122	38	74	34	69	28
Expected	....	516	96.8		64.5	129.0	32.2	64.5	32.2	64.5	32.2
Deviation	....	...	−7.8		−2.5	−7.0	5.8	9.5	1.8	4.5	−4.2

$\chi^2 = 4.5115$ P = .7185

TABLE 22.—CLASSIFICATION OF THE EARS IN FIVE F_2 PROGENIES FROM CROSS 1022 ($Pi_1Pi_1Pi_2Pi_2$ X $pi_1pi_1Pi_2pi_2$)

F_2 Progeny No.	F_1 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1022–1	$Pi_1pi_1Pi_2pi_2$	62	12		8	13	4	9	5	7	4
1022–2	(do.)	65	13		7	12	5	7	5	10	6
1022–3	(do.)	59	11		7	12	5	10	4	8	2
1022–4	(do.)	63	10		8	16	5	8	4	8	4
Total	....	249	46		30	53	19	34	18	33	16
Expected	....	249	46.7		31.1	62.2	15.6	31.1	15.6	31.1	15.6
Deviation	....	...	−.7		−1.1	−9.2	3.4	2.9	2.4	1.9	.4

$\chi^2 = 2.9171$ $P = .8912$

F_2 Progeny No.	F_1 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1022–5	$Pi_1pi_1Pi_2Pi_2$	54	13	....	26	....	....	....	15	....	....
Expected	....	54	13.5	....	27.0	....	....	....	13.5	....	....
Deviation	....	..	−.5	....	−1.0	....	....	....	1.5	....	....

$\chi^2 = .2222$ $P > .6065$

TABLE 23.—CLASSIFICATION OF THE EARS IN FOUR F_2 PROGENIES FROM CROSS 1015 ($Pi_1pi_1Pi_2pi_2$ X $Pi_1Pi_1Pi_2Pi_2$)

F_2 Progeny No.	F_1 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1015–1	$Pi_1Pi_1Pi_2pi_2$	191	143		....	....	48	....	....	....	....
Expected	....	191	143.2		....	....	47.8	....	....	....	....

Deviation = .2 ± 4.04 $\quad \frac{\text{Dev.}}{\text{P.E.}} = .05$

F_2 Progeny No.	F_1 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1015–9	$Pi_1pi_1Pi_2Pi_2$	240	57	....	123	....	....	....	60	....	....
1015–12	(do.)	85	21	....	42	....	....	....	22	....	....
1015–19	(do.)	242	60	....	118	....	....	....	64	....	....
Total	....	567	138	....	283	....	....	....	146	....	....
Expected	....	567	141.8	....	283.5	....	....	....	141.8	....	....
Deviation	....	...	−3.8	....	−.5	....	....	....	4.2	....	....

$\chi^2 = .2271 \qquad P > .6065$

TABLE 24.—CLASSIFICATION OF THE EARS IN TWO F_2 PROGENIES FROM CROSS 1002 ($Pi_1Pi_1pi_2pi_2$ X $pi_1pi_1pi_2pi_2$)

F_2 Progeny No.	F_1 Parent genotype	Total	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 pi_2pi_2
1002–4..........	$Pi_1pi_1pi_2pi_2$	156	39	75	42
1002–5..........	(do)	143	25	79	39
Total............	....	299	64	154	81
Expected.........	....	299	74.8	149.5	74.8
Deviation........	....	...	−10.8	4.5	6.2

χ^2 = 2.2087 P = .3377

TABLE 25.—CLASSIFICATION OF THE EARS IN FIVE F_2 PROGENIES FROM CROSS 1008 ($pi_1pi_1pi_2pi_2$ X $Pi_1pi_1Pi_2pi_2$)

F_2 Progeny No.	F_1 Parent genotype	Total	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1008–5...........	$pi_1pi_1Pi_2pi_2$	135	34	72	29
1008–9...........	(do.)	160	44	76	40
1008–14..........	(do.)	156	38	79	39
1008–15..........	(do.)	162	38	85	39
1008–16..........	(do.)	71	19	37	15
Total............	....	684	173	349	162
Expected.........	....	684	171	342	171
Deviation........	....	...	2	7	−9

χ^2 = .6404 P> .6065

TABLE 26.—CLASSIFICATION OF THE EARS IN A PROGENY OBTAINED FROM A BACK CROSS BETWEEN AN F_1 PLANT OF CROSS 1003 AND COUNTRY GENTLEMAN

Back cross progeny No.	Total	Pi_1pi_1 Pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1003B...............	79	24	19	18	18
Expected............	79	19.8	19.8	19.8	19.8
Deviation...........	..	4.2	−.8	−1.8	−1.8

χ^2 = 1.2504 P = .7440

TABLE 27.—CLASSIFICATION OF THE EARS IN TWO PROGENIES OBTAINED FROM BACK CROSSES BETWEEN F_1 PLANTS OF CROSS 1004 AND COUNTRY GENTLEMAN

Back cross progeny No.	Total	Pi_1pi_1 Pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1004C...............	85	17	20	25	23
1004D...............	90	21	23	26	20
Total...............	175	38	43	51	43
Expected............	175	43.8	43.8	43.8	43.8
Deviation...........	...	−5.8	−.8	7.2	−.8

χ^2 = 1.9808 P = .5768

TABLE 28.—CLASSIFICATION OF THE EARS IN SIX PROGENIES OBTAINED FROM BACK CROSSES BETWEEN F_1 PLANTS OF CROSS 1005 AND COUNTRY GENTLEMAN

Back cross progeny No.	Total	Pi_1pi_1 Pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1005A	60	15	15	14	16
1005B	102	23	29	30	20
1005C	73	24	20	16	13
1005D	51	7	9	19	16
1005E	86	18	19	26	23
1005F	26	8	5	5	8
Total	398	95	97	110	96
Expected	398	99.5	99.5	99.5	99.5
Deviation		−4.5	−2.5	10.5	−3.5

$\chi^2 = 1.4974$ $P = .6874$

TABLE 29.—CLASSIFICATION OF THE EARS IN TWO PROGENIES OBTAINED FROM BACK CROSSES BETWEEN F_1 PLANTS OF CROSS 1018 AND COUNTRY GENTLEMAN

Back cross progeny No.	Total	Pi_1pi_1 Pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1018B	124	28	31	35	30
1018C	88	23	18	20	27
Total	212	51	49	55	57
Expected	212	53.0	53.0	53.0	53.0
Deviation		−2.0	−4.0	2.0	4.0

$\chi^2 = .7548$ $P > .8065$

larger. The data show that the genetic composition of the F_1 parents can be best explained on the basis of the two-factor hypothesis. The behavior of the individual F_2 progenies is shown as follows:

For the segregation of:

$Pi_1\ Pi_1\ Pi_2\ pi_2$: Tables 32, 33, and 34
$Pi_1\ pi_1\ Pi_2\ Pi_2$: Table 35
$Pi_1\ pi_1\ pi_2\ pi_2$: Tables 30, 31, 32, and 33
$pi_1\ pi_1\ Pi_2\ pi_2$: Tables 31, 32, and 33

On the basis of the two-factor hypothesis there would be expected to be, in addition to the two parental types, two homozygous types, $Pi_1\ Pi_1\ pi_2\ pi_2$ and $pi_1\ pi_1\ Pi_2\ Pi_2$, both intermediate for kernel arrangement. This is confirmed by the data in Table 15. Seven progenies arising from selfed F_2 plants produced only ears of the $Pi_1\ Pi_1\ pi_2\ pi_2$ type. One other progeny so obtained produced only ears of the $pi_1\ pi_1\ Pi_2\ Pi_2$ type.

Rowing in Relation to Plant Characters

Comparisons between strains of Country Gentleman and Narrow Grain Evergreen sweet corn selfed for five successive years, indicate

TABLE 30.—CLASSIFICATION OF THE EARS IN SEVEN F_3 PROGENIES FROM CROSS 1003 ($Pi_1pl_1Pi_2Pi_2 \times Pi_1Pi_1pl_2pl_2$)

F_3 Progeny No.	F_2 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pl_2	Pi_1pl_1 Pi_2Pi_2	Pi_1pl_1 Pi_2pl_2	Pi_1Pi_1 pl_2pl_2	Pi_1pl_1 pl_2pl_2	pl_1pl_1 Pi_2Pi_2	pl_1pl_1 Pi_2pl_2	pl_1pl_1 pl_2pl_2
1003-7-5	$Pi_1pl_1Pi_2pl_2$	53	4		5	9	6	10	5	9	5
1003-12-2	(do.)	52	5		6	10	5	11	6	5	4
Total	....	105	9		11	19	11	21	11	14	9
Expected	....	105	19.7		13.1	26.2	6.6	13.1	6.6	13.1	6.6
Deviation	....	...	−10.7		−2.1	−7.2	4.4	7.9	4.4	.9	2.4
			$\chi^2 = 19.6921$			P = .0064					
1003-7-2	$Pi_1pl_1pl_2pl_2$	30	....		....	....	6	18	....	....	6
1003-7-3	(do.)	51	....		....	....	13	30	....	....	8
Total	....	81	....		....	....	19	48	....	....	14
Expected	....	81	....		....	....	20.2	40.5	....	....	20.2
Deviation	....	...	....		....	....	−1.2	7.5	....	....	−6.2
			$\chi^2 = 3.3632$			P = .1912					
1003-7-1	$Pi_1Pi_1pl_2pl_2$	58	...	....	....	....	58	....	....	....	....
1003-7-4	$Pi_1Pi_1Pi_2Pi_2$	46	46	....	....	....	....	....	....	....	....
1003-7-6	$Pi_1Pi_1pl_2pl_2$	27	...	....	....	....	27	....	....	....	....

TABLE 31.—CLASSIFICATION OF THE EARS IN SIX F_3 PROGENIES FROM CROSS 1018 ($Pi_1Pi_1Pi_2Pi_2$ X $pi_1pi_1pi_2pi_2$)

F_3 Progeny No.	F_2 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1018–9–1	$Pi_1pi_1Pi_2pi_2$	66	7		7	11	8	14	6	9	4
Expected	....	66	12.4		8.2	16.5	4.1	8.2	4.1	8.2	4.1
Deviation	....	..	−5.4		−1.2	−5.5	3.9	5.8	1.9	.8	−.1
			χ^2 = 13.1336		P = .0693						
1018–9–2	$Pi_1pi_1pi_2pi_2$	60	....		....	....	15	36	....	....	9
Expected	....	60	....		....	....	15	30	....	....	15
Deviation	....	..	....		....	....	0	6	....	....	−6
			χ^2 = 3.6000		P = .1704						
1018–2–2	$pi_1pi_1Pi_2pi_2$	57	....		....	....	....	....	14	27	16
1018–9–3	(do.)	97	....		....	....	....	....	27	44	26
1018–9–4	(do.)	81	....		....	....	....	....	19	41	21
Total	....	235	....		....	....	....	....	60	112	63
Expected	....	235	....		....	....	....	....	58.8	117.5	58.8
Deviation	....	...	....		....	....	....	....	1.2	−5.5	4.2
			χ^2 = .5819		P > .6065						
1018–2–1	$Pi_1Pi_1pi_2pi_2$	87	....		....	....	87	....	....	....	....

TABLE 32.—CLASSIFICATION OF THE EARS IN SIX F_3 PROGENIES FROM CROSS 1005 ($Pi_1Pi_1Pi_2Pi_2$ X $pi_1pi_1Pi_2pi_2$)

F_3 Progeny No.	F_2 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1005-18-1	$Pi_1pi_1Pi_2pi_2$	61	5		9	17	4	9	5	10	2
Expected	....	61	11.4		7.6	15.2	3.8	7.6	3.8	7.6	3.8
Deviation	....	..	−6.4		1.4	1.8	.2	1.4	1.2	2.4	−1.8
			$\chi^2 = 6.3219$			P = .5041					
1005-18-3	$Pi_1Pi_1Pi_2pi_2$	46	33		....	....	13	....	....	....	....
Expected	....	46	34.5		....	....	11.5	....	....	....	....
			Deviation = 1.5 ± 1.98			$\frac{\text{Dev.}}{\text{P.E.}} = .76$					
1005-2-3	$Pi_1pi_1pi_2pi_2$	61	....		....	....	16	35	....	....	10
1005-2-4	(do.)	69	....		....	....	17	37	....	....	15
Total	....	130	....		....	....	33	72	....	....	25
Expected	....	130	....		....	....	32.5	65.0	....	....	32.5
Deviation	....	...	....		....	....	.5	7.0	....	....	−7.5
			$\chi^2 = 2.4923$			P = .2966					
1005-2-1	$pi_1pi_1Pi_2pi_2$	57	....		....	....	....	....	13	31	13
Expected	....	57	....		....	....	....	....	14.2	28.5	14.2
Deviation	....	..	....		....	....	....	....	−1.2	2.5	−1.2
			$\chi^2 = .4221$			P > .6065					
1005-2-2	$Pi_1Pi_1pi_2pi_2$	70	....		....	....	70	....	....	....	....

TABLE 33.—CLASSIFICATION OF THE EARS IN NINE F_3 PROGENIES FROM CROSS 1004 ($Pi_1pi_1Pi_2pi_2$ X $Pi_1Pi_1Pi_2Pi_2$)

F_3 Progeny No.	F_2 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1004-15-1	$Pi_1pi_1pi_2pi_2$	49	....		....	....	12	25	....	....	12
1004-15-2	(do.)	32	....		....	....	9	16	....	....	7
Total	....	81	....		....	....	21	41	....	....	19
Expected	....	81	....		....	....	20.2	40.5	....	....	20.2
Deviation	....	..	....		....	....	.8	.5	....	....	−1.2
			χ^2 = .1092			P > .6065					
1004-15-3	$pi_1pi_1Pi_2pi_2$	63	....		....	....	....	....	12	31	20
1004-15-4	(do.)	66	....		....	....	....	....	24	27	15
1004-15-5	(do.)	85	....		....	....	....	....	24	39	22
Total	....	214	....		....	....	....	....	60	97	57
Expected	....	214	....		....	....	....	....	53.5	107.0	53.5
Deviation	....	...	....		....	....	....	....	6.5	−10.0	3.5
			χ^2 = 1.9533			P = .3790					
1004-10-4	$Pi_1Pi_1Pi_2pi_2$	59	44		....	....	15	....	....	....	....
Expected	....	59	44.2		....	....	14.8	....	....	....	....
			Deviation = .2 ± 2.24			$\frac{\text{Dev.}}{\text{P.E.}}$ = .09					
1004-10-1	$Pi_1Pi_1Pi_2Pi_2$	76	76	....	....	....	..	....	....	....	....
1004-10-2	(do.)	36	36	....	....	....	..	....	....	....	....
1004-10-3	$Pi_1Pi_1pi_2pi_2$	65	..	....	....	....	65	....	....	....	....

TABLE 34.—CLASSIFICATION OF THE EARS IN FOUR F_3 PROGENIES FROM CROSS 1010 ($pi_1pi_1pi_2pi_2$ X $Pi_1Pi_1Pi_2Pi_2$)

F_3 Progeny No.	F_2 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1010-2-3	$Pi_1Pi_1Pi_2pi_2$	51	36		....	....	15	....	....	....	....
1010-2-4	(do.)	52	39		....	....	13	....	....	....	....
Total	....	103	75		....	....	28	....	....	....	....
Expected	....	103	77.2		....	....	25.8	....	....	....	....

Deviation = 2.2 ± 2.96 $\frac{\text{Dev.}}{\text{P.E.}}$ = .74

F_3 Progeny No.	F_2 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1010-2-1	$Pi_1Pi_1Pi_2Pi_2$	45	45	....	....	....	....	....	....	....	....
1010-2-2	(do.)	18	18	....	....	....	....	....	....	....	....

TABLE 35.—CLASSIFICATION OF THE EARS IN THREE F_3 PROGENIES FROM CROSS 1015 ($Pi_1pi_1Pi_2pi_2$ X $Pi_1Pi_1Pi_2Pi_2$)

F_3 Progeny No.	F_2 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1015–19–1	$Pi_1pi_1Pi_2Pi_2$	47	12	....	23	....	....	....	12	....	....
1015–19–2	(do.)	69	17	....	33	....	....	....	19	....	....
1015–19–3	(do.)	53	12	....	28	....	....	....	13	....	....
Total	....	169	41	....	84	....	....	....	44	....	....
Expected	....	169	42.2	....	84.5	....	....	....	42.2	....	....
Deviation	....	...	−1.2	....	−.5	....	....	....	1.8	....	....

$\chi^2 = .1139$ $P > .6065$

TABLE 36.—CLASSIFICATION OF THE EARS IN THREE F_3 PROGENIES FROM CROSS 1006 ($Pi_1Pi_1Pi_2Pi_2$ X $pi_1pi_1pi_2pi_2$)

F_3 Progeny No.	F_2 Parent genotype	Total	Pi_1Pi_1 Pi_2Pi_2	Pi_1Pi_1 Pi_2pi_2	Pi_1pi_1 Pi_2Pi_2	Pi_1pi_1 Pi_2pi_2	Pi_1Pi_1 pi_2pi_2	Pi_1pi_1 pi_2pi_2	pi_1pi_1 Pi_2Pi_2	pi_1pi_1 Pi_2pi_2	pi_1pi_1 pi_2pi_2
1006–1–3	$Pi_1Pi_1pi_2pi_2$	65	....		....	....	65	....	..	....	....
1006–1–4	$pi_1pi_1Pi_2Pi_2$	76	....		....	....	..	....	76	....	....
1006–1–6	$Pi_1Pi_1pi_2pi_2$	70	....		....	....	70	....	..	....	....

that the latter, as a rule, produce more vigorous seedlings and larger plants altho the average number of days to maturity is about the same. Hybrids grown from crosses between selfed strains of Country Gentleman and Narrow Grain Evergreen are usually more vigorous than Country Gentleman intravarietal crosses. On the other hand, crosses between Narrow Grain Evergreen selfed strains are more vigorous than either. Repeated observations of this kind indicate that the rowed arrangement of kernels is associated with more vigorous growth and larger gross yields than the zigzag arrangement. It is not improbable, therefore, that the double recessive, zigzag kernel arrangement is associated with one or more plant characters which may segregate in a like manner.

PRACTICAL ASPECTS OF THE INHERITANCE OF ROWING

The inheritance of rowing is of particular interest to the breeder of Country Gentleman sweet corn. Since the zigzag character is a double recessive, a considerable percentage of rowed ears is bound to reappear each year in open-pollinated cultures. Most of these rowed ears will probably fall within Class III-B and a few possibly within Class III-A in cultures which have been carefully selected for a number of years. In commercial strains the range of segregation will usually be much wider.

It is very doubtful whether the breeder is justified in selecting only individuals of the pi_1 pi_1 pi_2 pi_2 phenotype. If the true zigzag arrangement is unduly emphasized, there is a possibility of reducing yields thru the inbreeding effect of close selection. The presence of phenotypes of pi_1 pi_1 Pi_2 Pi_2 and pi_1 pi_1 Pi_2 pi_2 composition is not objectionable from the commercial viewpoint. It is barely possible that all ears falling within Groups III and IV might be shelled together advantageously thus maintaining the culture in a heterozygous condition. Altho the evidence available is inconclusive, nevertheless the slight amount of rowing thus introduced may be associated with increased plant growth and better seedling vigor.

For the breeder of rowed varieties of sweet corn, the elimination of all but slight irregularities in rowing is a relatively simple matter owing to the incomplete dominance of rowing. It is probable that in spite of continued selection such genotypes as Pi_1 Pi_1 Pi_2 pi_2 and Pi_1 pi_1 Pi_2 Pi_2 will persist, but their presence does not detract from the value of the strain.

SUMMARY AND CONCLUSIONS

1. The rowed kernel arrangement in sweet corn is incompletely dominant over the zigzag arrangement, as shown by F_1 progenies.

2. Dihybrid segregations into eight classes in the F_2 generation establish the presence of two factors for rowing, Pi_1 and Pi_2.

3. This hypothesis is supported by monohybrid segregations in the F_2 and F_3 generations, of which no single progeny included both the distinctly rowed and the zigzag types.

4. Back crosses to the zigzag parent segregated into 1 $Pi_1 \cdot pi_1$ Pi_2 pi_2: 1 Pi_1 pi_1 pi_2 pi_2: 1 pi_1 pi_1 Pi_2 pi_2: 1 pi_1 pi_1 pi_2 pi_2.

5. Certain F_3 progenies proved homozygous for the intermediate types Pi_1 Pi_1 pi_2 pi_2 and pi_1 pi_1 Pi_2 Pi_2.

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